Measuring Consumer Willingness to Participate in BEV Smart Charging Programs

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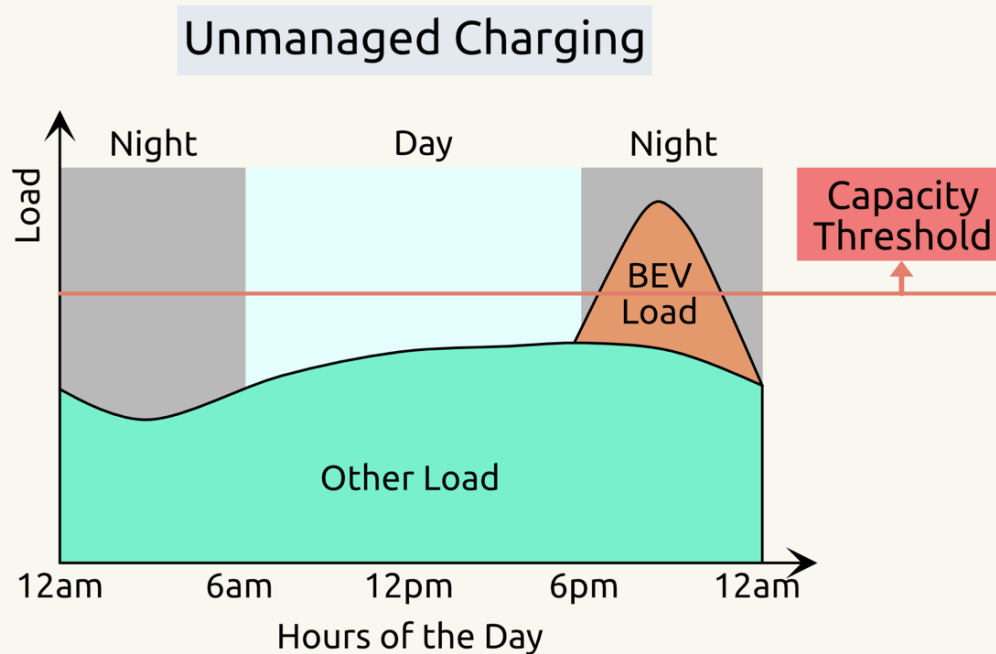
Introduction

- BEVs (Battery Electric Vehicles) can reduce CO_2 and prevent air pollution.

- But managing BEV charging can become a problem for the grid.
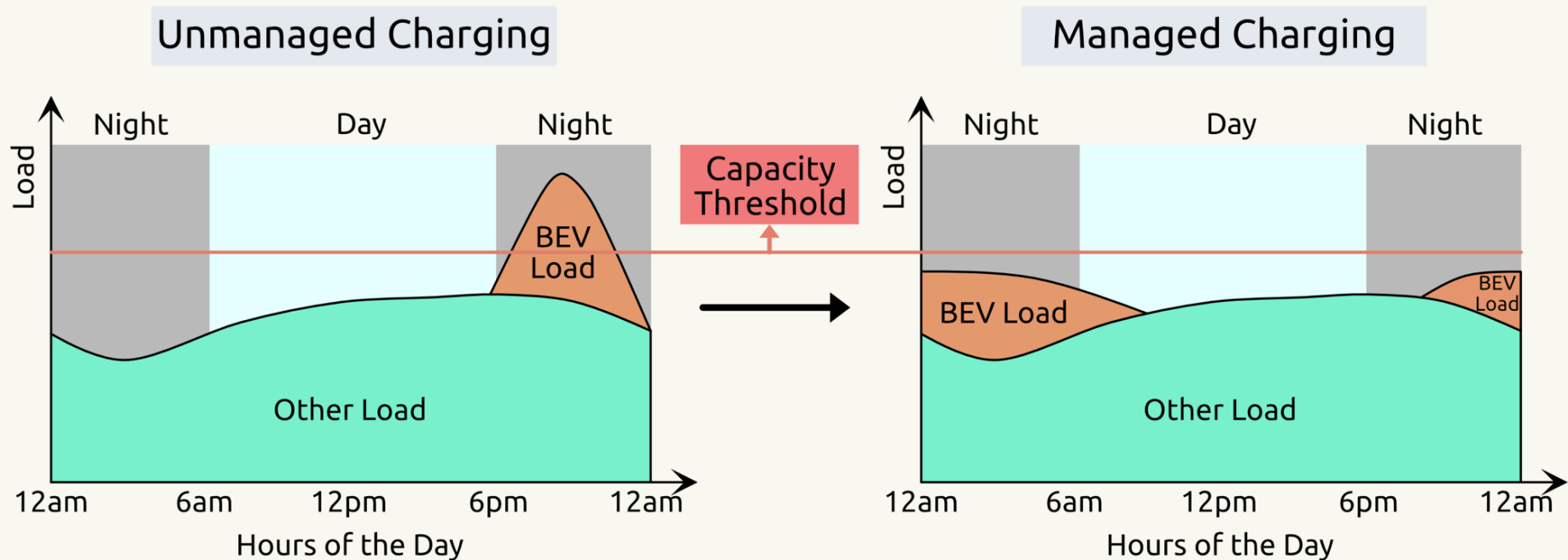
- Smart charging can help, but depends on user acceptance.

SMC - Supplier Managed Charging

- SMC smooths out overnight EV charging demand.
- Electricity demand is controlled below capacity threshold.

Unmanaged Charging

SMC - Supplier Managed Charging

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- Electricity demand is controlled below capacity threshold.

Unmanaged Charging

Night Day Night

Load

Capacity Threshold

BEV Load

Other Load

12am 6am 12pm 6pm 12am

Hours of the Day

Managed Charging

Night Day Night

Load

BEV Load

Other Load

BEV Load

12am 6am 12pm 6pm 12am

Hours of the Day

Managed charging avoids overload caused by BEV charging.

V2G - Vehicle-to-Grid

Non-V2G (Single Direction)

BEV   Charger   Grid

Figure Source: *wri.org*

V2G (Bi-direction)

BEV   V2G Device   Grid
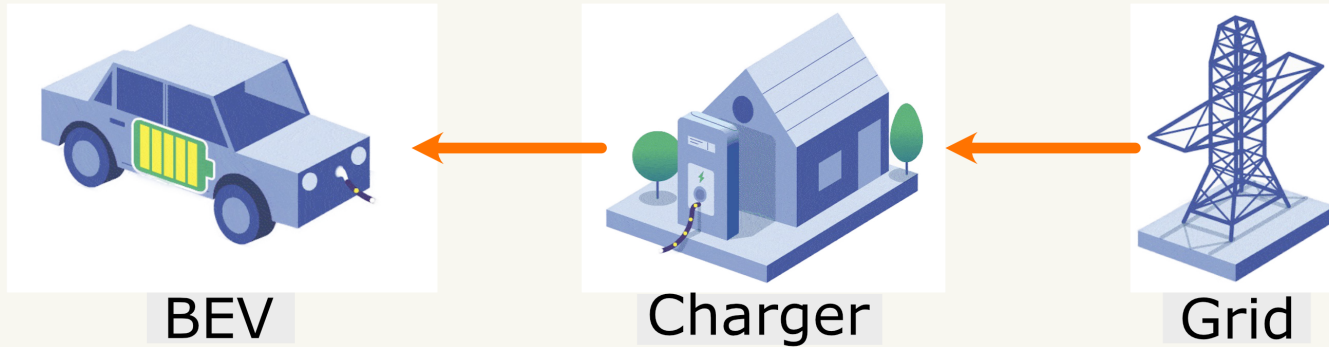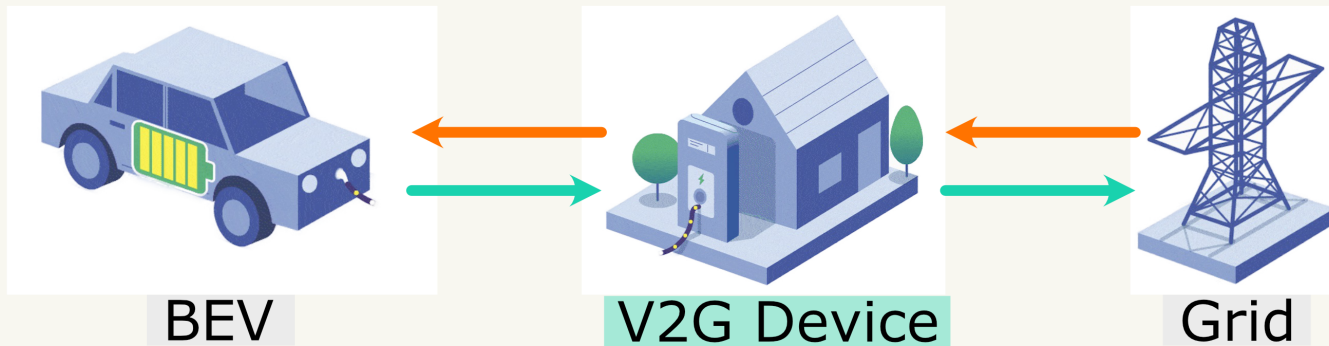
In a V2G event, BEVs can charge the grid when necessary. BEVs are charged back eventually. Owners earn money.

Research Questions

1. **Sensitivity**: How do changes in smart charging program features influence BEV owners' **willingness** to opt in?

2. **Market Share**: Under what **conditions** will BEV owners be more willing to opt in to smart charging programs?

Conjoint survey to collect BEV owners' willingness.

Mixed logit model to evaluate utilities for simulations.

Survey Design with formr

Survey Components

1. **Conjoint Questions:**

   a. Monetary Incentives

   b. Charging Limitations

   c. Flexibility

2. **Demographic Questions:**

   a. BEV Ownership & Usage

   b. Personal & Household Info

Conjoint Attributes Sample

No.	Attributes	Range
1	Enrollment Cash	$50 to $300
2	Monthly Cash	$2 to $20
3	Monthly Override	0 to 5
4	Min Battery	20% to 40%
5	Guaranteed Battery	60% to 80%

Conjoint Question Explained

A Sample Conjoint Question

For example, if these were the only apples available, which would you choose? *

Option 1	Option 2	Option 3
Type: Fuji	**Type**: Pink Lady	**Type**: Honeycrisp
Price: $ 2 / lb	**Price**: $ 1.5 / lb	**Price**: $ 2 / lb
Freshness: Average	**Freshness**: Excellent	**Freshness**: Poor

1. You are provided with different **sets** of attributes.

2. You choose one **set** instead of one **attribute**.
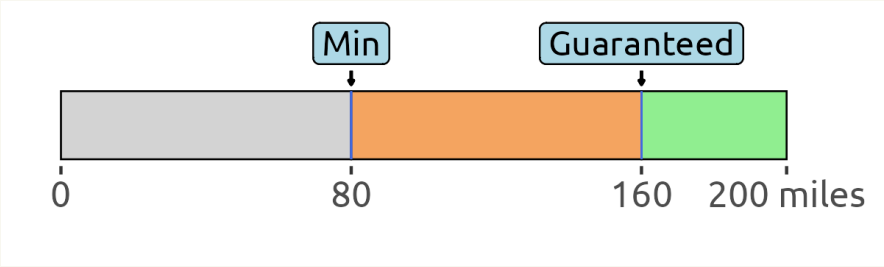
SMC Programs

Attributes

No.	Attributes	Range
1	Enrollment Cash	$50 to $300
2	Monthly Cash	$2 to $20
3	Monthly Override	0 to 5
4	Min Battery	20% to 40%
5	Guaranteed Battery	60% to 80%

Sample Program

Attributes	Values
Enrollment Cash	$300
Monthly Cash	$20
Monthly Override	5
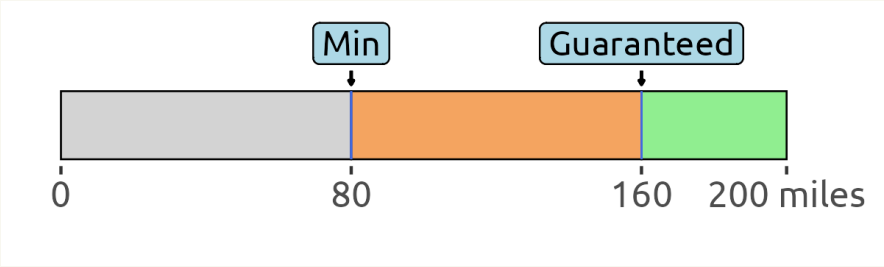
V2G Programs

Attributes

No.	Attributes	Range
1	Enrollment Cash	$50 to $300
2	Occurrence Cash	$2 to $20
3	Monthly Occurrence	1 to 4
4	Lower Bound	20% to 40%
5	Guaranteed Battery	60% to 80%

Sample Program

Attributes	Values
Enrollment Cash	$300
Occurrence Cash	$20
Monthly Occurrence	1
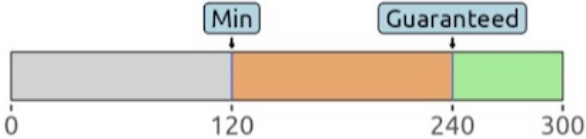
Min — Guaranteed

0   80   160   200 miles

Sample SMC Question

(1 of 6) If your utility offers you these 2 SMC programs, which one do you prefer?
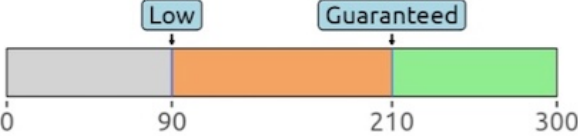(Your BEV has maximum range of **300** miles.)

Access the SMC Attributes

Option 1	**Option 2**	**Option 3**
Enrollment Cash: $100 Monthly Cash: $20 Override Allowance: 1 per Month Battery Thresholds (in Miles): Min ... Guaranteed 0 60 240 300	Enrollment Cash: $200 Monthly Cash: $10 Override Allowance: 1 per Month Battery Thresholds (in Miles): Min ... Guaranteed 0 120 240 300	Not Interested

Sample V2G Question

(1 of 6) If your utility offers you these 2 V2G programs, which one do you prefer? (Your BEV has maximum range of **300** miles.)

Access the V2G Attributes

Option 1	Option 2	Option 3
Enrollment Cash: $100 Occurrence Cash: $5 Monthly Occurrence: 2 Battery Thresholds (in Miles): Low — Guaranteed 0 90 210 300	Enrollment Cash: $100 Occurrence Cash: $20 Monthly Occurrence: 2 Battery Thresholds (in Miles): Low Guaranteed 0 120 180 300	Not Interested

Survey Fielding

- **Meta**: Facebook, Messenger, Instagram - **Voluntary**

- **4** months' of fielding from March to July in 2024
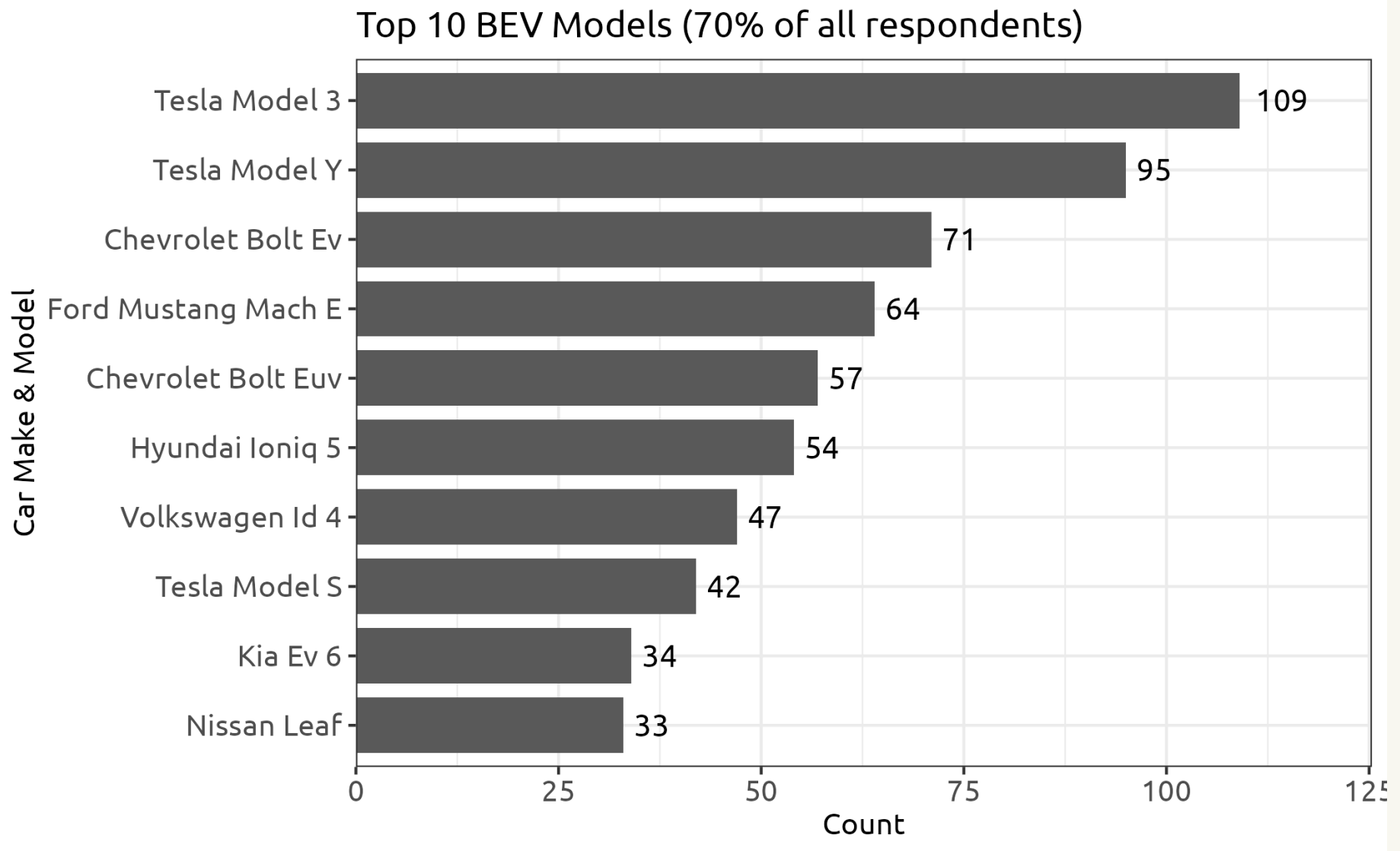
- **858** results after filtering
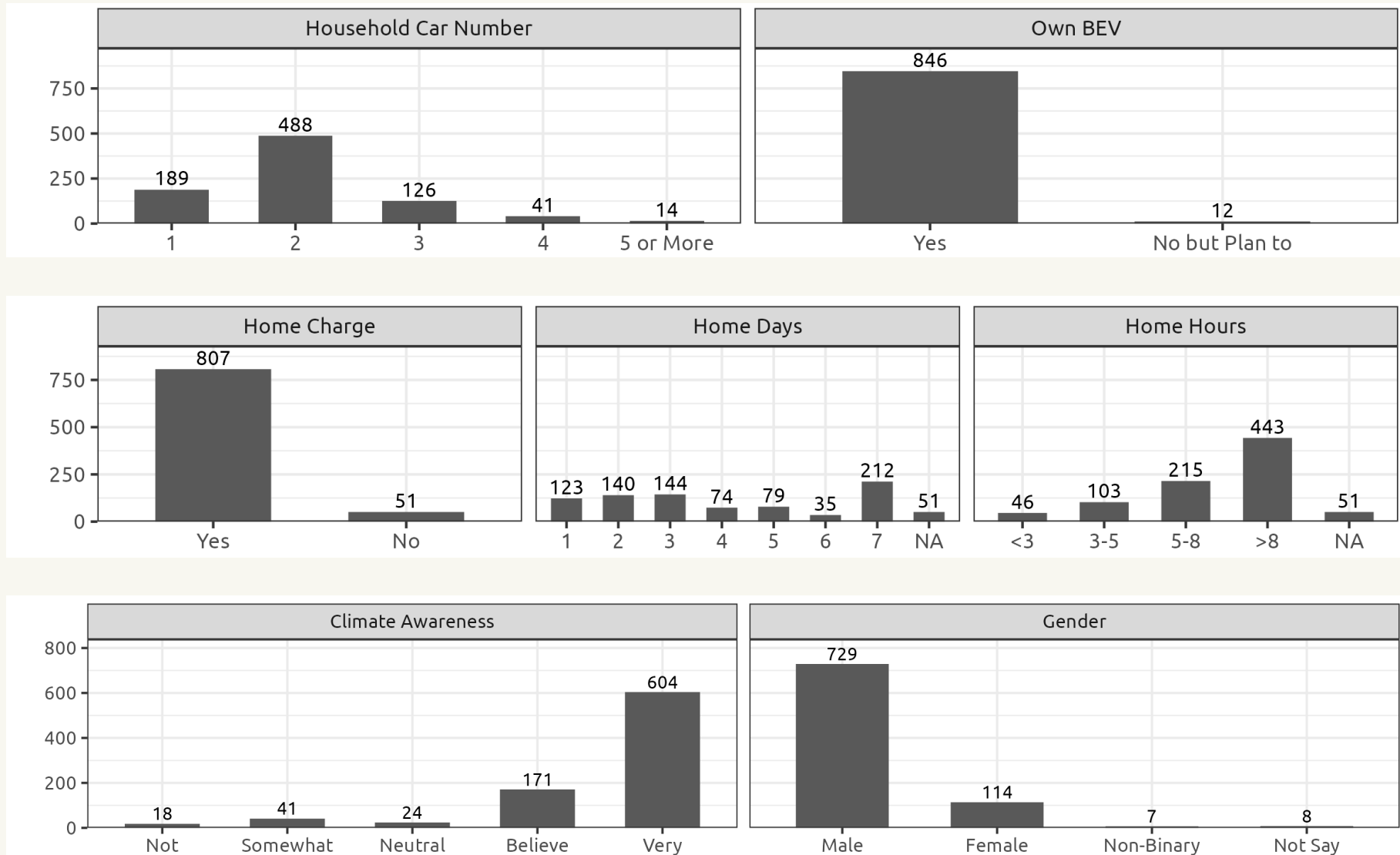

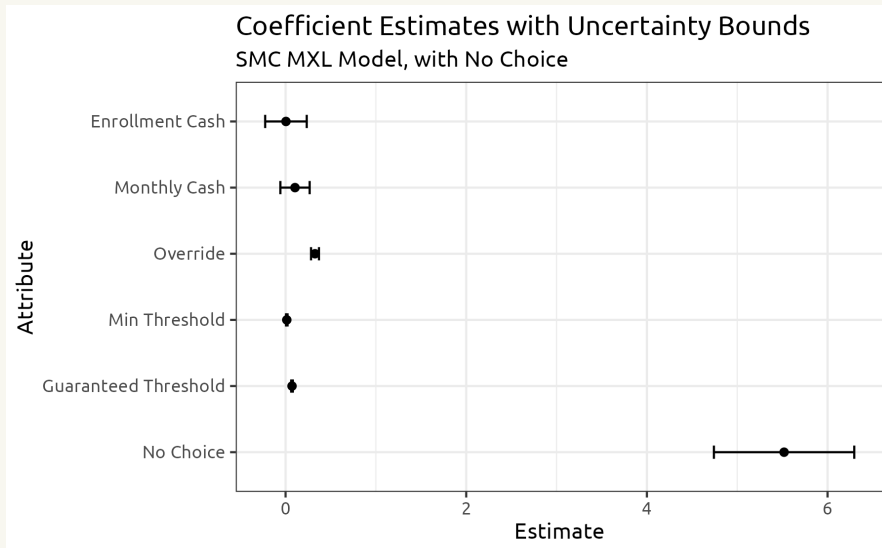Facebook   Messenger   Instagram

Survey Results - Top 10 BEV

Top 10 BEV Models (70% of all respondents)

Car Make & Model	Count
Tesla Model 3	109
Tesla Model Y	95
Chevrolet Bolt Ev	71
Ford Mustang Mach E	64
Chevrolet Bolt Euv	57
Hyundai Ioniq 5	54
Volkswagen Id 4	47
Tesla Model S	42
Kia Ev 6	34
Nissan Leaf	33

Survey Results - Demographics
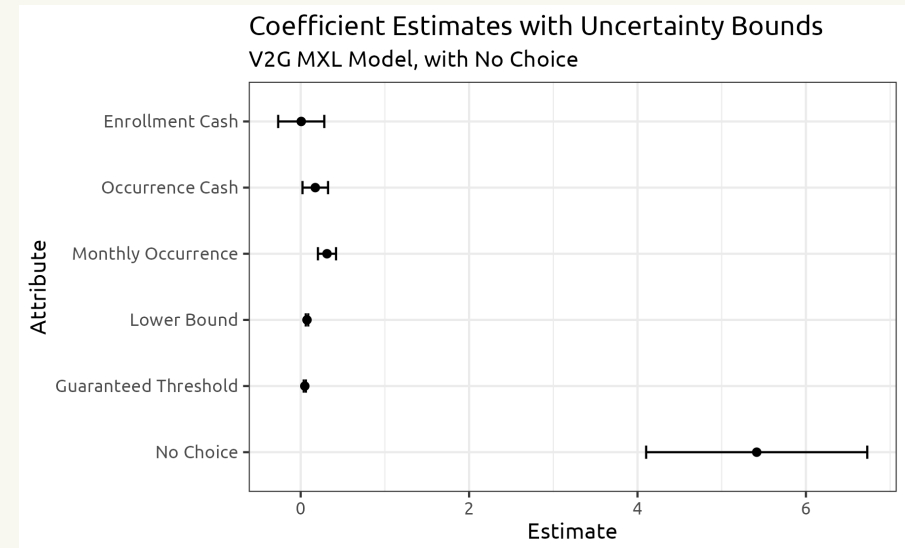
Survey Results - Willingness to Participate

Mixed Logit Models

$$u_j = v_j + \epsilon_j = \beta' x + \epsilon_j \qquad P_j = \frac{e^{v_j}}{\sum_{k=1}^{J} e^{v_k}}$$
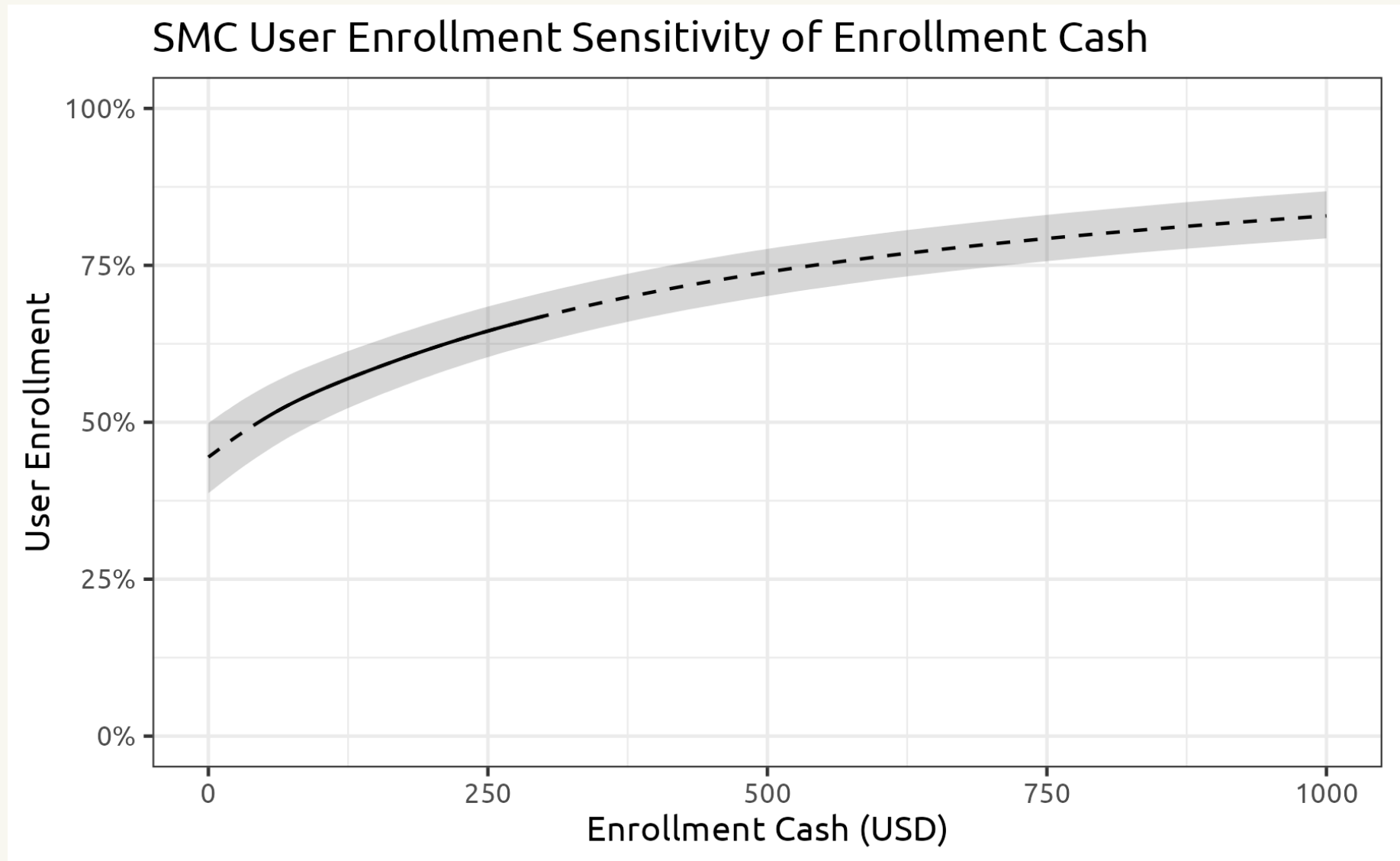
SMC Estimates

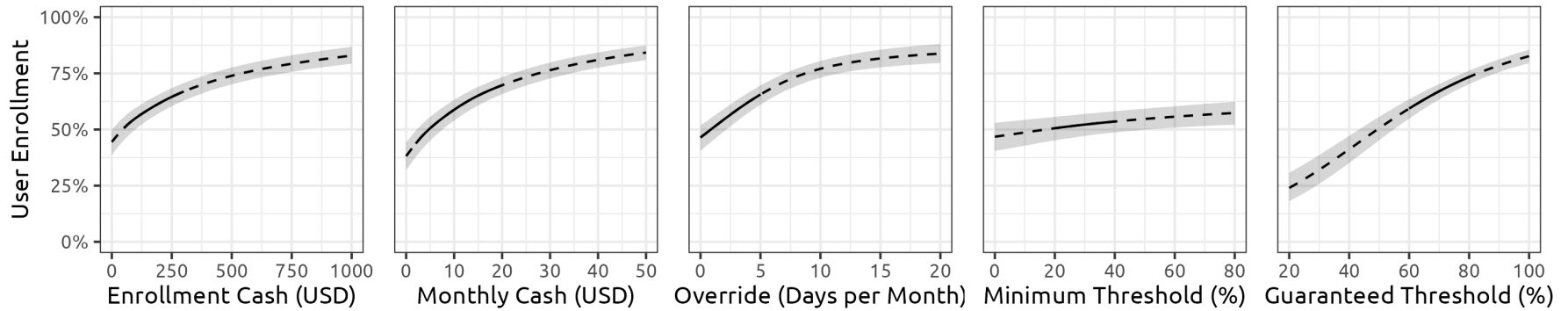
Coefficient Estimates with Uncertainty Bounds
SMC MXL Model, with No Choice

V2G Estimates

Coefficient Estimates with Uncertainty Bounds
V2G MXL Model, with No Choice

Without compensation, users will not participate.

Sensitivity Analysis

SMC User Enrollment Sensitivity of Enrollment Cash
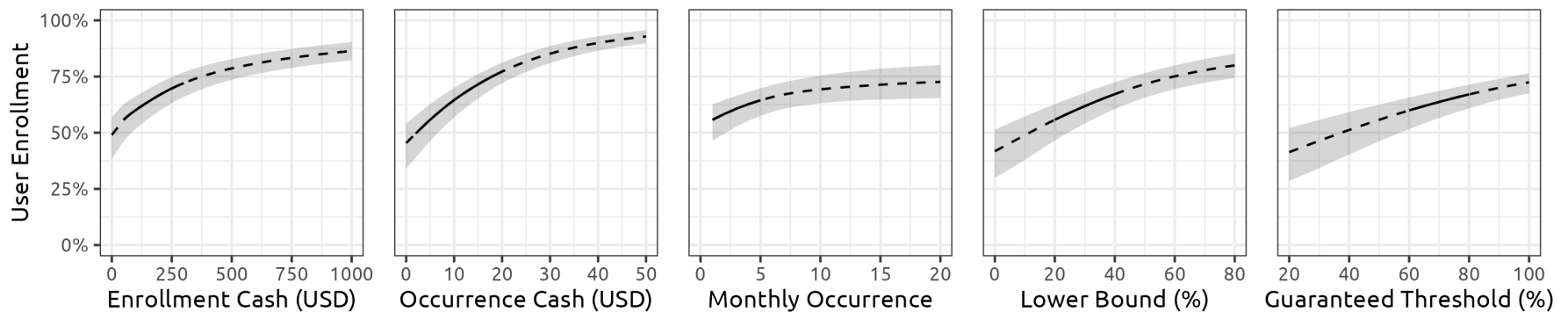
Sensitivity Analysis

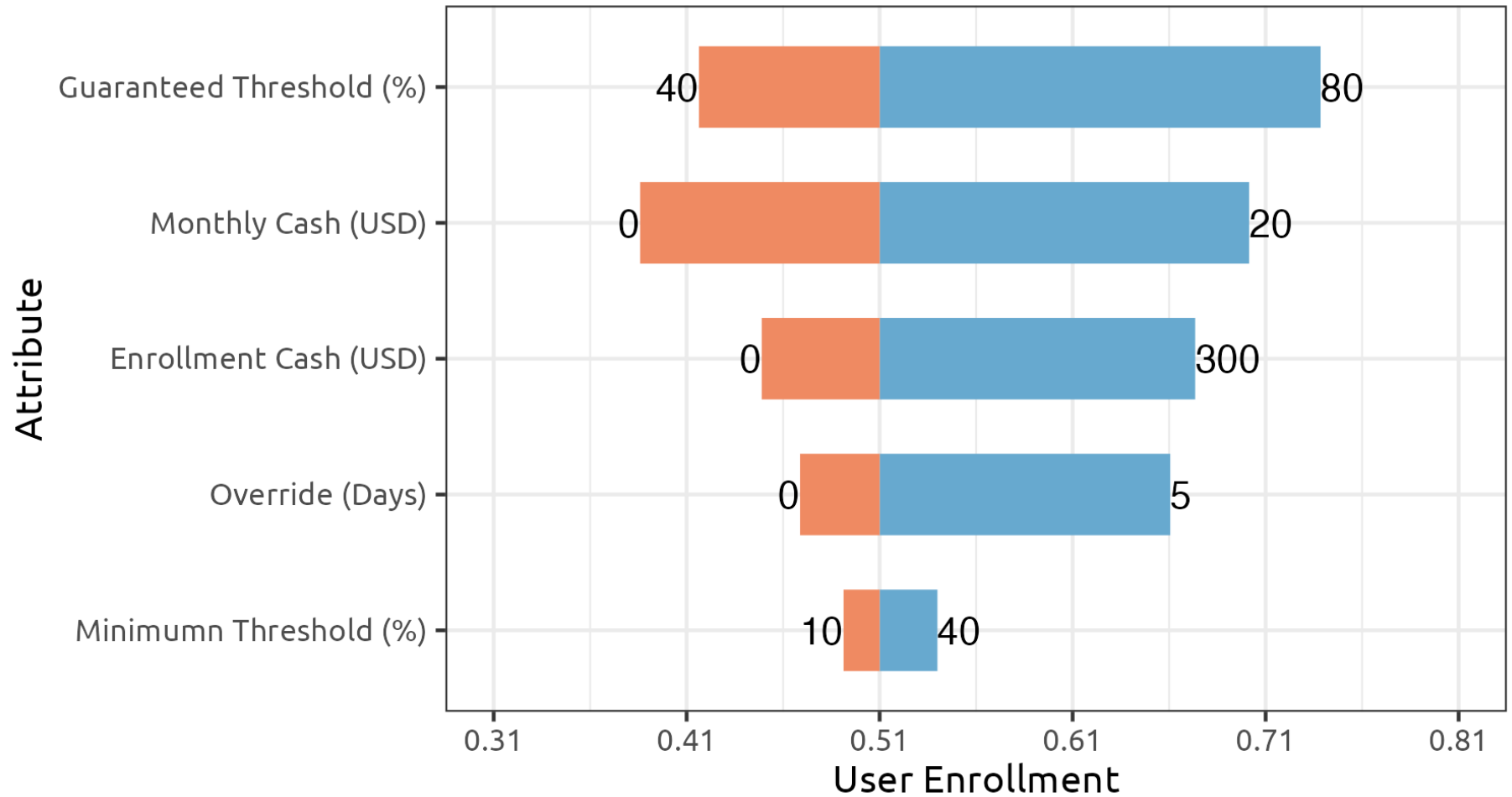SMC Sensitivity Plots

V2G Sensitivity Plots

Steeper slope indicates higher sensitivity.
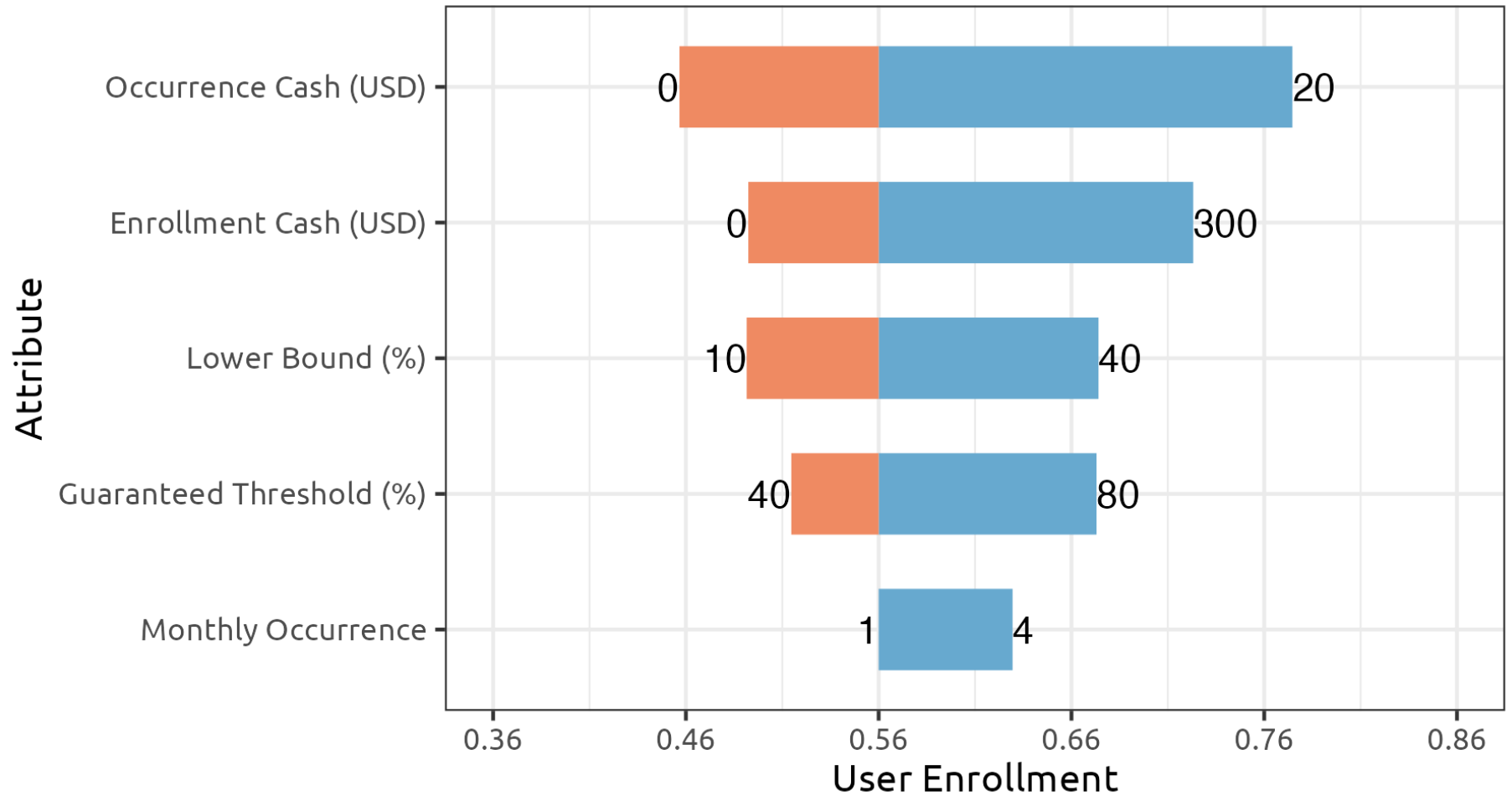
Tornado Plots - SMC

SMC Tornado Plot

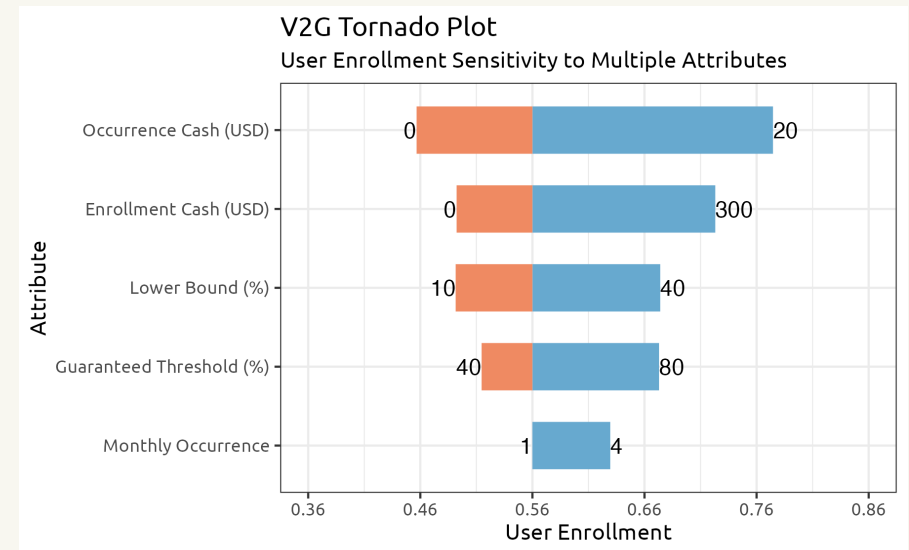User Enrollment Sensitivity to Multiple Attributes

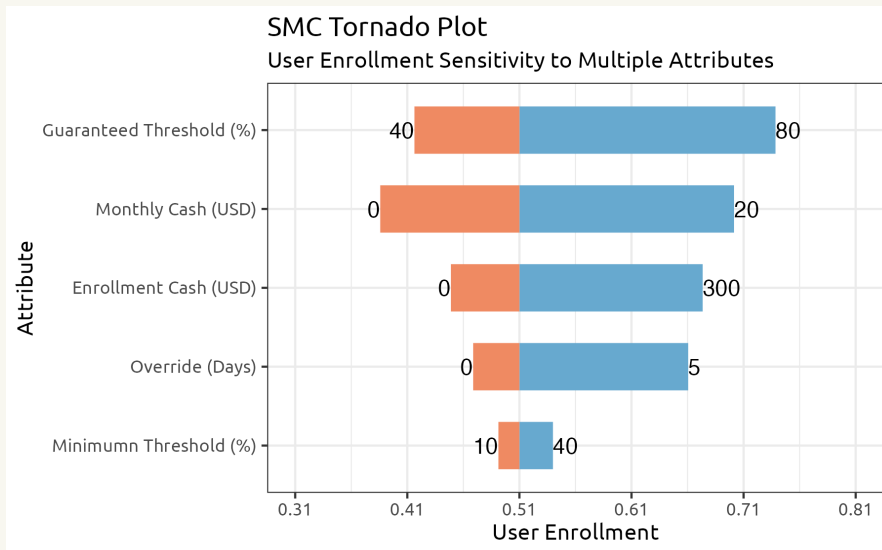# Tornado Plots - V2G

Tornado Plots - Summary

SMC Tornado Plot — User Enrollment Sensitivity to Multiple Attributes

V2G Tornado Plot — User Enrollment Sensitivity to Multiple Attributes
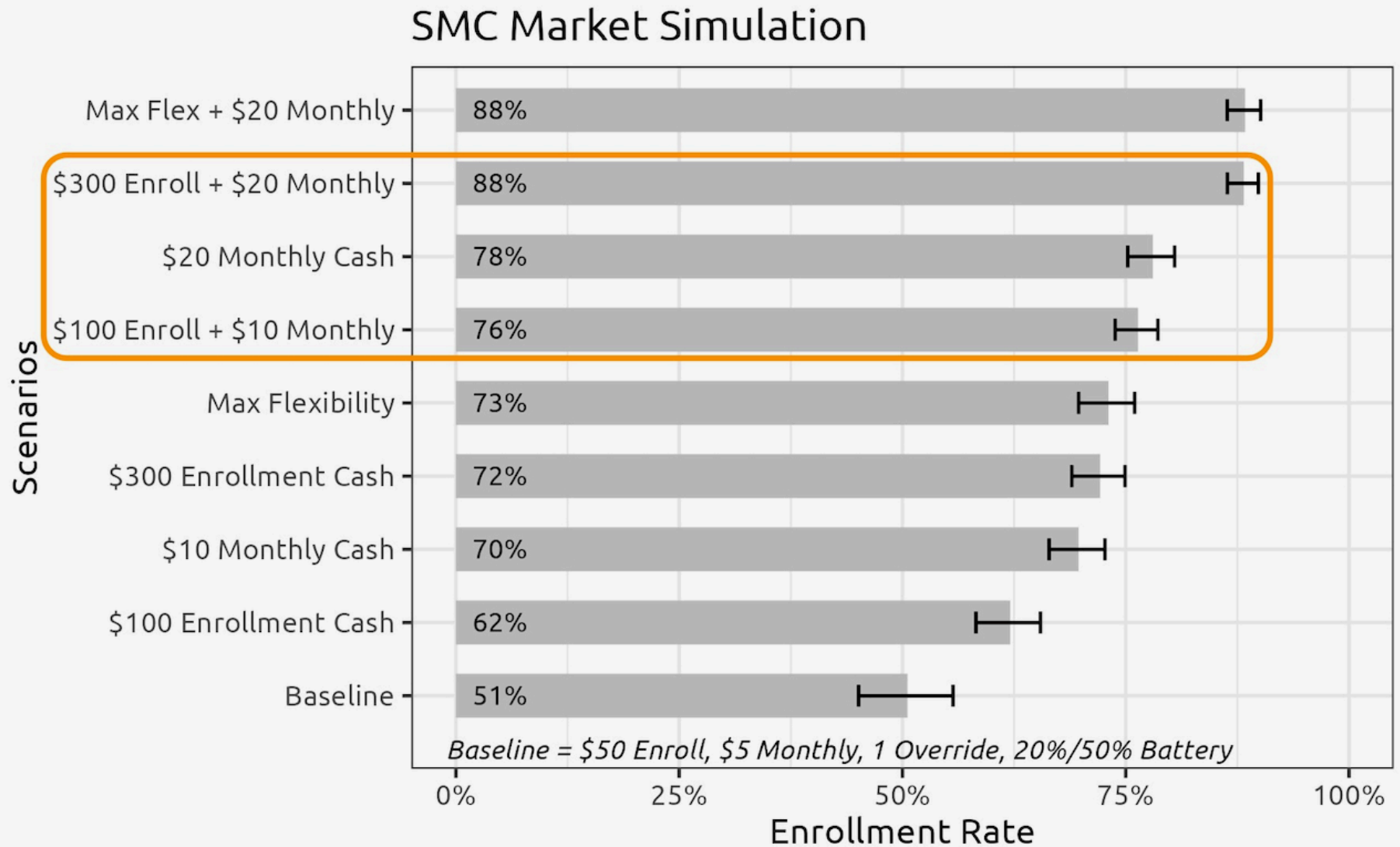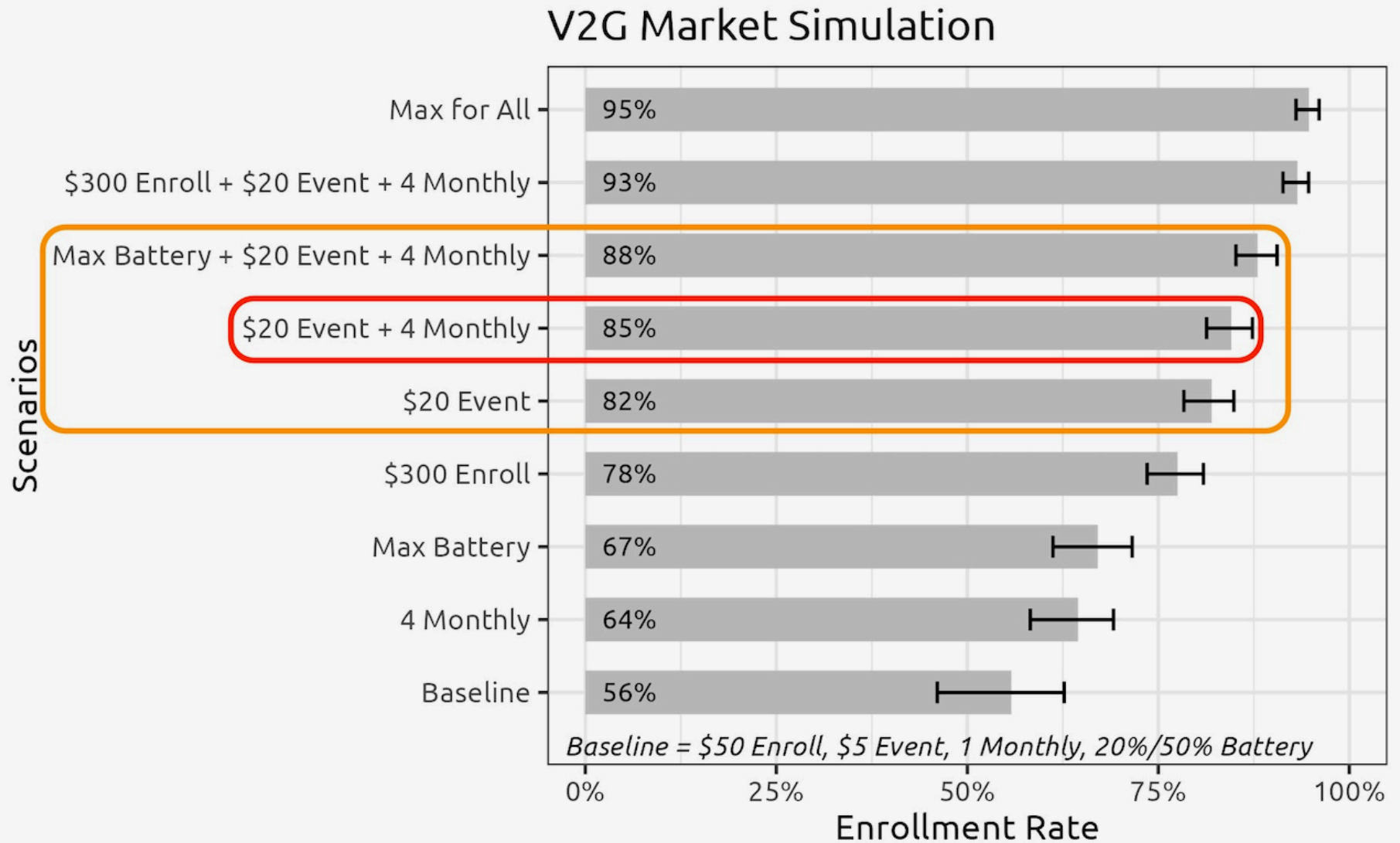
1. **Monetary** incentives are important.

2. **Recurring** incentives are more important than one-time.

3. For SMC, **range anxiety** is vital, since it happens regularly.

4. For V2G, usability is compromised.

5. Diminishing returns exist.

Market Simulation for SMC

SMC Market Simulation

Scenario	Enrollment Rate
Max Flex + $20 Monthly	88%
$300 Enroll + $20 Monthly	88%
$20 Monthly Cash	78%
$100 Enroll + $10 Monthly	76%
Max Flexibility	73%
$300 Enrollment Cash	72%
$10 Monthly Cash	70%
$100 Enrollment Cash	62%
Baseline	51%

Baseline = $50 Enroll, $5 Monthly, 1 Override, 20%/50% Battery

Market Simulation for V2G

Future Work

Data Collection

- Other than social media, use survey panels to collect more responses.

- Increase data size from 800 to 2000.

Modeling

- Subgroup analysis considering heterogeneity.

- More modeling techniques such as Apollo Choice Modeling.

Simulation

- Apply customer preferences to grid simulation.

- Estimate benefit-cost trade-offs for utilities.